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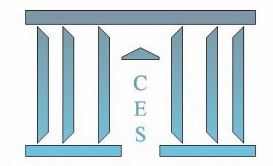

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Searching for Innovations ? The Technological Determinants of Acquisitions in the Pharmaceutical Industry

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Abstract

This article analyzes the individual determinants of acquisition activity and target choices in the pharmaceutical industry over the period 1978-2002. The "innovation gap" hypothesis states that acquiring firms lack promising drug compounds and acquire firms with more promising drug prospects. A duration model implemented over a panel of more than 400 firms relates the probabilities of being an purchaser or a target to financial, R&D and patent data to investigate this explanation more deeply. Results show that purchasers are firms with a lower Tobin's Q and decreasing sales, which could indicate that acquisitions are used to compensate for low internal growth prospects. Firms with a higher proportion of radical patents in their portfolio, especially in pharmaceutical and biotechnological patent classes, face a higher probability of being targeted, indicating that acquiring firms are indeed searching for innovative competencies. However, acquiring firms also present a significant absorptive capacity: their R&D investment increases in the year preceding the operation and their patent stock is larger and more diversified than for non-acquiring firms. Finally, we observe that over the last ten years of the sample period, firms have paid a greater attention to the size of the target's patent portfolio.

***J.E.L.* classification**: G34, L15, L21 and O3.
Keywords: M&A, Pharmaceutical, Innovations, Patent citations.

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I Introduction

The surge in acquisitions in high technology industries during the 1990s decade is well documented in both the popular and academic literatures. Over these years, the acquisition activity in the pharmaceutical industry has been particularly intense, with merger and acquisition (M&A) deals exceeding $500 billion in value (Danzon et al., 2004). Indeed, most of the leading pharmaceutical firms are the result or one or more horizontal mergers.[1] Besides such iconic mega–deals, the M&As of the 1990s also involved mid- and small-sized pharmaceutical firms and biotechnology companies either as targets but also as acquirers, as exemplified by deals like Biogen/Idec, both of them being biotech firms.[2]

Economic theory suggests several, not mutually exclusive, reasons for this acquisition activity. Merger waves can be triggered by industry–wide shocks, due to such factors as technological advances or deregulation, that can create excess capacity or accelerate obsolescence of some assets (for example, Hall, 1999; Andrade et al., 2001). In the pharmaceutical industry, the increasing roles played by both generic competition (especially since the Hatch-Waxman Act has been enacted in 1984, see Grabowski and Vernon, 1996) and biotechnology companies, may have forced established pharmaceutical firms to restructure in order to remain technologically competitive.[3] At an individual level, several factors are often presumed to influence the propensity of firms to acquire other companies or to be targeted. Horizontal mergers, notably between pharmaceutical firms, are often rationalized by economies of scale and scope particularly in R&D. Yet, the growing share of compounds produced by biotechnology firms and mid-sized pharmaceutical companies demonstrates that large size is clearly neither necessary, nor sufficient, to attain a high productivity

[1] For example, Glaxo-SmithKline's antecedents include Glaxo, Welcome, SmithKline French and Beecham; Aventis is the cross-national consolidation of Hoechst (German), Rhone-Poulenc (French), Rorer, Marion, Merrill, Dow (all US); Pfizer is the combination of Pfizer, Warner-Lambert, and Pharmacia, which included Upjohn. Danzon et al. report that, in 1985, the 10 most important pharmaceutical firms covered 20% of the world market versus 48% in 2002.

[2] See Pavlou (2003) and REUTERS (2004) for more examples of such operations.

[3] The increasing competition of generic drugs put into light the difficulties innovators have with the technological renewal since more and more drugs consumed are more than 20 years old.

in R&D. The pursuit of market power is also an implausible motivation given the low overall level of concentration in this industry and the divestiture requirements imposed by competition authorities. Both explanations are also at odds with the significant share of vertical deals occurring in the industry, notably between large diversified pharmaceutical firms and small biotechnology companies. Such operations can be related to asset specificity, but this hypothesis mostly explains the choice of the governance structure (within–firm organization as opposed to licensing or R&D partnerships), not the propensity to acquire or to be targeted.

More specific interpretations of the acquisition activity in pharmaceuticals have therefore been proposed. Danzon et al. (2004), Ornaghi (2005) and Higgins and Rodriguez (2006) relate this acquisition process to the excess development, production and marketing capacities owned by pharmaceutical firms. Indeed, in the 1990s, growth and revenue prospects in the pharmaceutical industry have been declining, as more drugs were coming off exclusivity protection than were being replaced by new Food & Drug Administration (FDA) approved chemical entities. Forthcoming "pipeline gaps" are making fixed development, production and sales capacities redundant, forcing the pharmaceutical firms to either divest such assets or to outsource new compounds that could fill in these "gaps". On the other hand, smaller and more innovative companies face more and more obstacles as their drug candidates evolve through development stages, clinical testings and regulatory approval. Thus stated, the "pipeline gap" hypothesis is merely an example of established firms acquiring more innovative but cash-strained companies thanks to large financial capacities, a process already observed in other high-technology industries (Blonigen and Taylor, 2000; Dessyllas and Hughes, 2005a,b).

Because the paper will focus on innovations (as reflected from the firms' patent portfolios) rather than on pharmaceutical compositions being developed or approved by regulatory authorities, we label this explanation the "innovation gap" hypothesis and extend it by specifying two complementary assumptions. Based on the homony-

mous concept developed by Cohen and Levinthal (1989), the "absorptive capacity" hypothesis states that the acquisition of technological knowledge embodied in other organizations' physical or human capital is efficient when, and only when, the acquiring firms maintain an internal R&D program to identify and benefit from external sources of knowledge. Hence, the innovation gap should not be so large as to prevent the acquiring firm from fully exploiting the research opportunities generated by the acquired unit(s). Absorptive capacity had already been found to be relevant when considering interfirm collaboration (Belderbos et al., 2004; Cassiman and Veugelers, 2002; Cassiman et al., 2005) as well as the matching of partners in mergers and acquisitions (Frey and Hussinger, 2006) but had not been investigated in the context of pharmaceutical mergers and acquisitions.

What we term the "patent portfolio" hypothesis states that acquiring firms do not (only) search for more innovative units, but merely or also seek to augment the size of their patent portfolios in order to better protect existing inventions and to conduct research more freely. Indeed, over the last twenty years, patents have turned out to be a decisive factor in shaping the firms' innovative activities (Lerner, 1995; Hall and Ziedonis, 2001; Ziedonis, 2003; Wagner and Parchomovsky, 2005; Graham and Higgins, 2006). The pro-patent stance and the burst of technological innovations have generated a surge in patenting, which is being considered suspiciously by both policy analysts and firms (Kortum and Lerner, 1999; Hall, 2005). One accusation is that the proliferation of patents rights renders R&D activities more lengthy and costly: firms have to cautiously search and negotiate any patent claims they may infringe for fear that the holder later blocks the commercialization and obtains very favorable infringement damages, settlement payments or licensing fees. One solution chosen by firms to alleviate these difficulties (but one that also aggravates them on aggregate) is to build up large patent portfolios in order to be able to countersuit any infringement, to negotiate favorable licensing terms and cross–licensing deals and to conduct research more freely and at a lower cost. The build-up of such large patent

portfolios may proceed through internal R&D investments, but could more efficiently be achieved through mergers and acquisitions. In the pharmaceutical industry, this acquisition motivation should have gained more prominence in the recent years as the bio-pharmaceutical industry increasingly resembles a "complex" industry where new products are likely to incorporate or be enforced through multiple patents sometimes hold by different companies.

To explore the relevance of these three hypothesis in the pharmaceutical industry, this paper uses an unbalanced panel of 409 firms including 660 acquisition operations and 162 target firms in the 1978-2002 period. Compared to the previous research on acquisition activity by pharmaceutical firms, our data's main specificity is to incorporate detailed data on the firms' patent portfolios, including patent technology classes and citations, thereby allowing us to approach the innovation gap hypothesis through a new filter and to complement it with new aspects related to the absorptive capacity and the build-up of larger patent portfolios. The following contributions to the literature are made.

First, in support of the "innovation gap" hypothesis, we do observe that targeted firms hold a patent portfolio with a higher proportion of "radical patents", those being defined as receiving more citations and making less citations than the median of patents in the same year and patent class. Thus, acquired units present more promising patent portfolios than other, non-acquired, firms. Acquiring firms also suffer from a lower Tobin' Q and from a lower R&D stock than non-acquiring units, elements which were interpreted as supporting evidence to the "innovation gap" hypothesis in previous research.

Second, we find evidence that acquiring firms still benefit from a significant absorptive capacity. Their patent portfolio is larger than those of non-acquiring units as well as more diversified across technological units. There is no evidence that the acquiring firms' patent portfolios lack promising items compared to non-acquiring companies. Acquiring firms also increase their R&D investment prior to making an

acquisition, indicating that internal R&D investment and R&D outsourcing through acquisitions are at least partly complementary.

Finally, over the whole 1978-2002 period considered here, there is no strong evidence corroborating the patent portfolio hypothesis. The patent yield (i.e., the number of granted patents divided by the R&D stock) is not significant in any of our regressions. The size of the targets' patent portfolio does not turn out to be a significant selection criteria, except (weakly) in the case of biotechnology patents. However, we also observe that in the 1993-2002 subperiod, firms with large patent portfolios in pharmaceuticals or biotechnology are more likely to be targeted, while firms with small overall patent portfolios are more likely to launch acquisition operations. This confirms that over the recent years, patents as legal tools have come to play a stronger role in corporate strategies than had previously been observed.

The paper is organized as follows. In section II, we review the theoretical intuitions and the past empirical literature on acquisition strategies in high–technology industries. In section III, we describe our data and our empirical methodology. The independent variables are presented in section IV. Section V discusses the results of our estimation and section VI concludes.

II Survey and Hypothesis Formulation

As outlined above, this article explores the empirical relevance of three complementary hypotheses to explain the individual determinants of acquisition activity.

1 The "Innovation Gap" Hypothesis

One of the most popular explanations of acquisition waves in high technologies is that, periodically, technological change in those industries is so rapid, drastic or uncertain that large incumbent firms need to turn to smaller, more reactive companies as sources of technological change (Chesbrough, 2003). In the pharmaceutical and bio–

pharmaceutical industries, economists and management analysts have long stressed the incentive and informational advantages of smaller companies in coping with technological change (Danzon et al., 2004; Filson and Morales, 2006). In this setting, acquisitions of innovative firms are a deliberate, long–term strategy, but they can also result from less deterministic circumstances. Short-term financial losses can trigger a slowdown in R&D activity, which, years later, translates into fewer innovative products so that the acquisition of more innovative units is needed to shore up the firm's growth potential. The uncertainty associated with innovation and especially valuable innovations could also motivate the acquisitions of more innovative companies: firms may maintain very substantial R&D efforts, but will use acquisitions in those periods when they have a below average realization of valuable innovations. There are indeed numerous examples of managers using acquisitions to compensate for low in–house R&D investment or innovative potential. Pharmaceutical firms very often explain their acquisition patterns by the need to incorporate drug compounds into their drug pipelines[4] and similar patterns can be found in other high–technology industries.

Empirically, the need to turn to external sources of innovation has been proxied through R&D intensity by Blonigen and Taylor (2000), whose analysis of a sample of 531 acquisitions by more than 200 US electronic and electrical equipment firms during the period 1985-93 shows that the probability and the number of acquisitions made by a firm decreases with its R&D intensity. This result has since been confirmed by Dessyllas and Hughes (2005a) over a sample on 5,064 acquisitions initiated by more than a thousand acquiring firms in high–technology industries during the 1984-1997 period. The citation–weighted patent intensity of a firm (which they define as the ratio of the citation-weighted number of patents to the firm's total as-

[4]Hence, Higgins and Rodriguez (2006) quote a *Gilead Sciences'* representative explaining the acquisition of Triangle Pharmaceuticals : "*We had a need to build our pipeline. This acquisition brings to Gilead not only a late-stage product that could launch next year, but a pipeline of other drugs in development*". Similarly, the acquisition of *Aton Pharmaceuticals* by *Merck Co.* was explained in the following terms by a company representative: "*The acquisition ... will enhance its* [Merck] *internal research efforts to develop potential new medicines for the treatment of cancer.*". Another example is *AstraZeneca* planning to acquire Arrow Therapeutics to "*broaden its anti-infective offerings* [...] *after the recent loss of several of its most promising late–stage candidates*" (*Pharmaceutical Business Review Online*, February, 2nd, 2007).

sets) is also negatively related to its probability of making an acquisition. Hence, such firms apparently devoted a lower share of their assets to R&D and innovation, but used the spared financial capacity to acquire innovative firms. Indeed, in a companion paper based on a sample of 328 acquisitions in high–technology industries, Dessyllas and Hughes (2005b) observe that a higher R&D intensity increases the probability to be targeted, and so does the stock of patents, regardless of whether it is citation–weighted or not. Using a sample of 405 acquired firms in the 1998-2000 period, Ali-Yrrkö (2006) conclude that Swedish potential targets with more European patents have a higher probability of being acquired by foreign firms.

The empirical evidence gathered by Danzon et al. (2004), Ornaghi (2005) and Higgins and Rodriguez (2006) for the pharmaceutical industry broadly fits into the innovation gap hypothesis.[5] They all observe that acquisitions are likelier to be decided by firms facing patent expirations on their blockbusters and gaps in their pipeline of new drugs. It is uncertain however whether these "pipeline gaps" and the needed acquisitions result from a substantial and deliberate reduction in R&D budgeting or from unexpected delays, cancelations and failures in the development program.

Despite these supporting empirical results, the innovation gap hypothesis still suffers from both theoretical and empirical caveats. Starting with the latter, Frey and Hussinger (2006)'s analysis of 458 European M&A deals concludes that the R&D intensity of the potential target firm has a *negative* impact on the probability of being acquired. In Dessyllas and Hughes (2005b), firms with a lower Tobin's Q face a higher probability of being targeted – and their companion paper concludes that acquiring firms present a higher Tobin's Q (Dessyllas and Hughes, 2005a). Given that the Tobin's Q is usually interpreted as a proxy for growth prospects, such results sit at odds with the innovation gap hypothesis. The determinants of target choices in

[5] Ornaghi (2005) uses a duration model to estimate the occurrence of 168 acquisitions among a sample of 1726 firms over the 1989-2001 period. Danzon et al. (2004) use a multinomial logit over a sample of 165 "transforming mergers" among a sample of around 200 firms per year over the 1988-2000 period. Higgins and Rodriguez (2006) run probit regressions over a sample of 160 operations over the 1994-2001 period.

the pharmaceutical industry are not absolutely coherent with the innovation gap hypothesis either. Indeed, firms with the highest growth prospects (in terms of Tobin's Q) are less likely to be targeted (Danzon et al., 2004). In other industries, Ali-Yrrkö et al. (2005) did conclude that Finnish firms owning a patent had a higher probability of being acquired by a foreign firm (not by a Finnish firm possibly because their own technological capital was not strong enough), but Ali-Yrrkö (2006) did not find that the number of citations to the patent stock of a firm is a determinant of its probability to be acquired. More generally speaking, several studies of cross–industry samples (Addanki, 1986; Hall, 1999) had previously concluded that targets were low–performing innovators[6] or firms mired in financial difficulties in terms of liquidity or operating returns (Dessyllas and Hughes, 2005b).

From a theoretical standpoint, the "innovation gap" hypothesis probably underestimates the difficulties associated with the acquisitions of innovative firms, in terms of target valuation and post-acquisition integration for instance. Hence, it may be used only to acquire innovative firms that detain either innovations or innovative potential that the acquiring firms is unable to replicate internally. Second, the question of what is actually acquired is seldom considered. Indeed, we can imagine that the acquiring firm is merely seeking to enhance its product portfolio (by acquiring firms with drug compounds close to market approvals for instance) or its patent portfolio (in which case it will target firms with a large patent portfolio). This strategy could be of particular relevance in the biotechnology industry where patents have become crucial to a firm's competitiveness. Alternatively, its objective may also be to enhance its innovative potential by incorporating more R&D efficient units into its own R&D structure. Then, the focus will probably be on some indicator of R&D performance like the proportion of valuable patents over total patent stock.[7] Finally, another lim-

[6]For instance, using a sample of 116 takeovers of high-tech US public firms during the period 1977-1984, Addanki (1986) finds that firms that do R&D but have no patents are likely to be targets in takeovers and that the probability of being acquired is negatively related to the number of patents. Using a sample of 861 manufacturing acquisitions in the US during the period 1976-1993, Hall (1999) also finds that targets with a particularly high R&D-intensity (more than 50%) are less likely to be acquired.

[7]Such a distinction regarding the type of acquisitions is also informative about the long-term strat-

itation of the innovation gap hypothesis is that no attention is paid to the absorptive capacity of the acquiring firm, i.e., its ability to effectively identify and exploit the innovative products or innovative abilities of the potential targets.

2 The "absorptive capacity" hypothesis

What we term the "absorptive capacity" hypothesis states that while knowledge gaps can be a stimulus to taking over more innovative firms, the acquiring firm should have enough knowledge capital in–house to identify promising knowledge, patents and innovations in potential targets as well to integrate and combine them effectively with the existing R&D capital within the firm (Cohen and Levinthal, 1989; Arora and Gambardella, 1990; Zander and Kogut, 1995; Teece et al., 1997; Zahra and George, 2002)). This issue might be of particular relevance when one considers the difficulties involved in the valuation of the target's knowledge assets and in the integration of these assets into the acquirer's knowledge base (Chaudhuri and Tabrizi, 1999; Connor, 2001; Puranam et al., 2006).

Popular proxies that have been used to capture this absorptive capacity in recent empirical studies on the innovation and cooperation behavior of firms include firms' R&D assets (Stock et al., 2001; Cassiman and Veugelers, 2002; Belderbos et al., 2004) as well as patent stocks, especially when combined with prior art citations (DeCarolis and Deeds, 1999; Kira, 2006). Other literature has identified the importance of in-house basic science research to develop this capability, particularly when the external science from which the firm draws is of a basic nature (Cockburn and R., 1998; Zucker et al., 2002; Markiewicz, 2006).

If acquirers were not really interested in the long-term viability of the innovative capabilities of targets and these transactions were one-time transfers of technology

egy followed by established pharmaceutical or biotechnology firms. The first type of acquisitions could reflect a long-term division of innovative labour between established companies and smaller, more innovative, upstarts. The second type more closely resembles a corporate strategy aiming at fostering the firm's long-term innovative capacities.

(after which the target's technical team becomes redundant), then one could discount the need for an absorptive capacity before acquisitions. However, interviews with corporate development managers in the information and telecommunication industries by Puranam et al. (2006) tend to show that acquirers actually seek to broader innovative abilities.[8]

Accordingly, the acquiring firms'absorptive capacity does seem to influence the acquisition process. Higgins and Rodriguez (2006) find that pharmaceutical firms with a greater R&D intensity have a higher propensity to undertake R&D acquisitions, a result which, they say, is consistent with the notion of absorptive capacity. Valentini (2004) also finds that R&D intensity is a significant driver of acquiring another firm in the US sector for medical devices and photographic equipment in the period 1988-1996. Further, Dessyllas and Hughes (2005a) find that acquiring firms sit on a larger patent stock than non-acquisitive firms, regardless of whether this stock is weighted by citations or not.

Support for the "absorptive capacity" hypothesis can also be traced through the selection of targets. Hence, Hall (1987) concludes that firms of like sizes and R&D intensity are more likely to merge and the shadow price of the target firm's R&D intensity increases in the acquiring firm's own R&D intensity. Frey and Hussinger (2006) observe that if the potential target and the acquiring firm applied for at least one EPO patent in the past, a merger is more likely to occur, indicating that a target firm with patents is of higher interest to innovative acquiring firms. Hussinger (2005), Marco and Rausser (2001) and Frey and Hussinger (2006) find that the degree of relatedness between an acquirer's and a target's technological fields has a large positive impact on the probability of a merger: a patenting target firm is more

[8]Hence, one manager from *Hewlett-Packard* said "*Usually we purchase a specific piece of technology or a product. But that is only half the story, we also want the team which will generate innovation in the future*". Another, from *Cisco Systems* echoed this view : "*For us it is never the box or the block that is already here- it's all about the next generation product.*" A manager from *Intel* specifically stated that this was one of the criteria they used to select targets: "*When looking at a target we typically ask, will the technology be developed? Will the team stick around? Will there be a next generation product?*".

attractive for the acquiring firm if both firms patent in related technological fields. Finally, the absorption capacity assumption is also supported by several studies finding that mergers have a more significant positive impact on R&D intensity in the case of complementary technological assets (Ahuja and Katila, 2001; Cassiman et al., 2005; Valentini, 2004).

3 The "patent portfolio" hypothesis

The predictions of the innovation gap hypothesis as well as of the absorptive capacity hypothesis merely use patents as proxies of the innovation capital. Yet, the pro-patent shift in the US courts may have strengthened the role that patents *as legal tools* can play in acquisition strategies for two distinct yet complementary reasons.

First, the strengthening of the intellectual property rights associated to patent grants have increased their economic value. For instance, the pro-patent reforms of the mid-1980s allowed several large firms, like *IBM* or *Texas Instruments*, to implement more intensive patenting and enforcement practices generating very substantial license fees. In the pharmaceutical industry, the patents detained by small biotechnology firms are forcing large pharmaceutical firms to spend increasing sums in the licensing-in of these patent–protected drug compounds (Nicholson et al., 2002; REUTERS, 2004). Anecdotal evidence also reveals a weakening bargaining power of large pharmaceutical firms due to their lack of internal development prospects, the growing pool of pharmaceutical companies searching to tap into biotechnology research and the growing financial resources of the biotechnology companies (REUTERS, 2004). In this context, the pharmaceutical firms could reason that they are better off buying smaller, more innovative companies rather than licensing in some of their compounds. Total licensing revenues would be transferred to the acquirer. The operation could also increase the bargaining power of the patent owner as well as generate synergies in patent portfolio management. On a more strategic ground, the pharmaceutical firm could yield a better control over the diffusion

of the innovation (notably to competitors). Finally, the integration of the targeted unit within the organizational structure of the acquirer (implying better control and coordination) could increase the R&D productivity of the unit.[9]

Second, the "pro-patent" shift in the US courts combined with the development of new technologies like semiconductors, software, telecommunications and biotechnology coincided with an unprecedented surge in the number of patent applications. Both as a cause and a consequence of this surge in patenting, the incentives to patent and to hold a large patent portfolio have been greatly expanded (Cohen et al., 2000). Indeed, given the high rate of patenting and the complexity of the innovations in high-technology industries, the costs and legal risks of pursuing R&D projects around overlapping patent and claims may have been substantially increased. In this context, a large patent portfolio will avoid lengthy patent infringement procedures as threats of countersuits should facilitate the negotiation of favorable licensing or cross–licensing deals (Hall and Ziedonis, 2001; Somaya, 2003; Ziedonis, 2003; Lanjouw and Schankerman, 2004b). In turn, the R&D projects will not be impeded by legal uncertainty and the firm's ability to explore distinct research fields will be enhanced by the assurance that patent protection has already been obtained in these various segments. Holding a patent portfolio can also have a multiplier effect on the range of innovations that can be accessed externally by the firm because large patent portfolios can encourage upstart innovators to combine their inventions with that of the portfolio holder rather than develop their own market niche (Lerner, 1995). Finally, large patent portfolios also enhance the holder's bargaining position over potential licensees who may fear numerous patent infringements. In this setting, holders of small patent portfolios may have to acquire or merge with other companies in order to increase the size of their patent portfolio and better exploit their R&D potential.

Whether the patent portfolio hypothesis applies to the acquisition operations made

[9]Indeed, several studies point to a rather large failure ratio of the licensing/R&D collaboration agreements between pharmaceutical firms and biotechnology companies (REUTERS, 2004; Kale et al., 2002).

in the pharmaceutical industry remains uncertain (Dratler, 2006; Graham and Higgins, 2006; Epstein and Kuhlik, 2006). Indeed, the rationale for patent portfolio acquisitions mainly applies to so called "complex industries" where new marketable product or processes are comprised of numerous separately patentable elements (Cohen et al., 2000). Oppositely, new drugs or chemicals are typically made of a very limited number of patentable elements and the surge in patenting has been very moderate in the pharmaceutical industry.[10] Nonetheless, some subsegments of the pharmaceutical industries fit into the definition of complex industries, like medical instruments or biotechnology. In this latter, a successful drug or treatment method may require combining various patentable gene fragments and pharmaceutical processes.

Examples of acquisitions motivated by patent–related concerns abound. Yahoo's acquisition of Overture was at least partly motivated by the growing patent portfolios held by Yahoo's rivals *Google*, *Microsoft* and *Amazon* in algorithmic and sponsored search patents.[11] In the pharmaceutical industry, the acquisition of DNT by StarPharma in 2006 was apparently driven by the will to create the largest patent portfolio in the research segment[12] thereby blocking rival research activities and attracting larger pharmaceutical firms into an M&A deal. Yet the empirical evidence supporting such motives remains very scarce so far. While several studies include patent stocks in regressions of acquisition or target propensities, they do not separate the patent portfolio effect from that of technological capital. Estimations by Marco and Rausser (2001) indicate that acquisitions in agricultural industry are primarily launched by firms whose patent portfolio lack enforcement effectiveness and target companies with more enforceable patents. Graff et al. (2003)complement these result by observing that agricultural firms use acquisitions to get hold of patents in distinct but complementary research fields.

[10] Actually, from 1986 to 1993, the number of patents per million of R&D investment in the semiconductor industry rose from 0.2 to 0.3, but decreased from 0.2 to 0.1 in the pharmaceutical industry (Hall and Ziedonis, 2001).

[11] See: http://news.com.com/$2100-1024_3-1027084$.html

[12] *BioShares*, October, 13th, Issue 188, "*The rationale behind StarPharma's acquisition of DNT*").

III Dataset and Empirical Methodology

1 Dataset

Our dataset combines firm-level economic, financial and patent data. Merging these distinct information sources was made possible by the common use of the CUSIP (*Committee on Uniform Security Identification Procedure*) code to identify firms. In a first step, we collected information on acquisitions involving at least one biopharmaceutical company for the 1978-2005 period. Acquisitions are defined as deals where the acquiring firm owns less than 50% of target's voting shares before the takeover and increases its ownership to at least 50% as a result of the takeover. Data are retrieved from *Thomson Financial's Securities Data Corporation* (SDC). Biopharmaceutical companies were identified using SDC's "business description" and "sector" variables.

Second, economic and financial data on pharmaceutical companies were retrieved from the *Standard and Poor's Compustat* database. Several of our independent variables are built from these indicators, like the R&D stock, the Tobin's Q or the variation in stock market value (*cf. infra*). Each of these variables is corrected for inflation through the OECD price index (normalized to 100 in 2002). These data are merged with the SDC sample of acquisition and target operations and the resulting sample comprises those firms listed in the SDC set of operations, as well as all the pharmaceutical firms identified through the sector SIC code 283x ("Medicinal chemicals and botanical products", "Pharmaceutical preparations", "In vitro and in vivo diagnostic substances", "Biological products except diagnostic substances") by *Compustat*. Compared to the *Compustat* classification, the SDC industry classification proposes a relatively large definition of the pharmaceutical activities. Also remember that only one firm needs to belong to the pharmaceutical industry for the operation to be included in the sample. Consequently, not all the firms involved in acquisition operations have a pharmaceutical SIC code. A large share of these firms belong to the

medical apparatus and instruments industry (SIC codes of 3841-45). Finally, the rest of our firms are large companies spanning multiple industries (including drugs) but whose main activity is not in the pharmaceutical sector.[13]

This dataset was finally merged to the patent database provided by the NBER (Hall et al., 2001). For each granted patent, cited patents ("backward citations" or "citations made") and citing patents ("forward citations" or "citations received") were collected in order to define indicators patent quality.

At the end of this process, the dataset comprises 409 firms involved in 660 acquisition operations and 162 target operations between 1978 and 2002, with a total number of firm–year observations of 5620.

2 Empirical Methodology

Like Hall (1999), Marco and Rausser (2001) or Ornaghi (2005), we estimate a duration model measuring the probability with which firms will pursue acquisitions or be targeted. In both the acquirer and the target estimation, we model this probability as a hazard function that depends upon individual firms' characteristics. The two models are similar, so we will outline the theory using the probability of acquisition.

The firm will choose to make an acquisition in the next small interval of time when the value of doing so exceeds the reservation value (the status quo). We assume the choice set is (almost) the same for all firms, so the only distinguishing characteristics are the characteristics of the potential purchaser. Accordingly, we model the probability of a firm making an acquisition at time t as a function only of the firm's characteristics and the characteristics of the market (the industry dummies). The hazard function, $\gamma(t)$, gives the probability that the firm will undertake an acquisition given that it has not made an acquisition for t years. The hazard function

[13] For instance, *American Cyanamid*, *DuPont de Nemours*, *Hoechst*, *ICN Biomedicals Inc.*, are classified into "Chemicals" (SIC code 2800).

is defined as $\gamma(t) = \frac{f(t)}{1-F(t)}$, where $f(t)$ and $F(t)$ are the usual density and cumulative probability functions.

The exponential specification assumes a constant hazard: $\gamma(t) = \gamma$, so that the hazard function does not vary with time. That is, there is no duration dependence; the length of time a firm has gone without a merger does not, ceteris paribus, affect the likelihood of merger in the next interval of time. The hazard rate is constant in t if $1 - F(t)$ is distributed according to the exponential distribution. The parameter γ is modeled as $\gamma = e^{X\beta+\epsilon}$ where X is a matrix of firm and market characteristics (given in Table 1). The Cox proportional hazards model specifies a hazard function of $\gamma(t_i) = exp(-\beta x_i)\gamma_0(t_i)$ for each firm i. γ_0 is a baseline hazard function common to all firms and is adjusted by the exponential coefficient. The Cox representation is semi-parametric because only the β_k 's are estimated: γ_0 is left unspecified. This allows us to assess the effect of (changing) covariates on hazard rates without having to impose a particular shape for the baseline hazard. Estimations are thus made through maximum likelihood.[14]

IV Independent Variables

1 Financial Variables

Several financial variables are used in our regressions. The market value of the firm is defined as the sum of the value of common stock, the value of preferred stock, the value of long-term debt, and the value of short term debt net of assets (Hall *et al.* 2005). There are several interpretations that can be made from this variable. Danzon et al. (2004) use it to explore the motive for scale economies, implying a negative coefficient sign (which they do not obtain). Alternatively, a higher market value makes acquisitions relatively less costly, so that a positive sign is expected. In the phar-

[14]The absence of a need to parameterize time dependency is a significant advantage because previous works on M&A determinants do not allow us to specify a priori what distribution should be used, and in many cases, the parameterization chosen can have a non-marginal impact on the results.

maceutical and bio-pharmaceutical industry, both Danzon et al. (2004) and Ornaghi (2005) conclude to a positive influence of market value upon the probability of acquisition. Regarding potential targets, a higher market value makes the operation more costly but it also increases the value of the deal: the bundle of assets is larger and probably more complex so that buying them separately may not be feasible. Danzon et al. observes a positive relationship between market value and the probability of being acquired. Several papers also note that targets present a higher stock of total assets at the time of operation (Frey and Hussinger, 2006; Dessyllas and Hughes, 2005a).

The growth in market value during the three years preceding the year of operation (from $t-3$ to $t-1$) is also included in the regressions. A low growth rate could force the firm to acquire other companies in order to find new profit opportunities. On the other, a high growth rate of market value could facilitate the financing of the operations. Ornaghi (2005) uses a similar variable but cannot discern any significant influence.

The Tobin's Q is defined as the ratio of the market value and of the book value of assets. The book value is the sum of the net plant and equipment, inventories, and investment in unconsolidated subsidiaries and intangibles. We interpret this indicator as a proxy for future growth. Indeed, given that the main sources of growth for pharmaceutical and bio-pharmaceutical firms (know-how, patents) are not very well captured by standard accountancy measures, these growth prospects may yet transpire through a higher market value, thereby increasing the Tobin's Q. This proxy is used by both Danzon et al. (2004) and Ornaghi (2005), who observe that acquiring firms have a lower Tobin's Q.[15] On the other hand, Dessyllas and Hughes (2005a) obtain a positive coefficient. Regarding targets, those with a higher Tobin's Q could be more attractive as well as more expansive. Following the corporate control hy-

[15] Danzon et al. also note that the influence of the Tobin's Q disappears when estimates include the number and the age of drugs marketed by the firm, which confirms the relevance of using the Tobin's Q as a proxy for future growth.

pothesis, firms with a low q are probably badly managed, making them easier to purchase. Danzon et al. (2004) finds a negative relationship between the Tobin's Q and the probability of being targeted, and so do Dessyllas and Hughes (2005b).

2 R&D Related Data

Whether acquisitions are used to compensate for a lack of internal innovation capacities can also be investigated through R&D related variables. Indeed, DiMasi et al. (2003) indicate that the cost of development of new drugs has greatly increased in the 1980s and 1990s. Thus, maintaining a constant rhythm of innovations necessitates increasing R&D expenses. Oppositely, firms with a low R&D capital may need acquisitions to integrate potential innovations. Given that acquiring new units necessitates an absorption capacity, potential acquiring firms may increase their R&D investment before their M&A. Thus, two distinct variables are used in our regressions, the R&D stock, measured through the perpetual inventory model with declining balance depreciation[16] and the growth rate of R&D investment in the three years preceding the operation. Ornaghi (2005) observes that for large pharmaceutical firms, the R&D expenses incurred the year before the acquisition have a negative impact on the probability of making an acquisition.

3 Patent Related Data

Several indicators are built from the NBER patent dataset (Hall et al., 2001) in order to evaluate the innovative performance of potential targets and acquiring firms as well as their patent portfolio. If the innovation gap theory is extended onto patent portfolios and innovative capacities, acquiring firms are expected to have a relative small patent portfolio, to have a low patent yield and/or to have patent portfolios of low average "quality" as measured by forward and backward patent citations.

The patent stock is calculated using the perpetual inventory method using a con-

[16] See Hall (1990).

stant depreciation rate of 15%. The patent yield is defined as the number of granted patents divided by the stock of R&D (Lanjouw and Schankerman, 2004b). The regressions use the 4-year mobile average preceding the year of examination to account for the uncertainty and random variations associated to year-by-year patent grants. Because patents are a very noisy measure of technological change and innovative potential, we try to correct for this heterogeneity in patent value by incorporating backward and forward citation counts. As shown in figure 1, we define a radical or pioneer patent as one that has:

1. *received* more citations than the median number of received citations for patents belonging to the same class and granted the same year (forward citations)

   and

2. *made* less citations than the median number of received citations for patents belonging to the same class and granted the same year (backward citations).

Thus, these "radical" patents are less dependent on past inventions than the median patent granted that year, and yet they exert a greater influence on future technological developments (than the median patent granted that year). We might therefore expect these patents to generate greater scientific and economic prospects.

One final variable that we use in our regressions is the Herfindahl-Hirschmann concentration rate of the patent portfolio over technological classes. Each patent is assigned to a primary USPTO technological class but a patent portfolio can span several technological classes. Summing the squared share of each technological class in a firm's patent portfolio yields the technological concentration index (TCI) of the patent portfolio: $TCI = \sum_{k=1}^{N_i} s^2$ where s is the share of patents in technological class k and N_i the total number of technological classes firm i's patents have been assigned to. Again, the variable used in the regressions is the 4-year mobile average to account for the random variations in patent grants and technology classes assignments.

Except for the technological concentration index, all the patent variables will be calculated at three distinct levels: over all the patent portfolio owned by the firm, over only the pharmaceutical and bio-pharmaceutical patents (USPTO patent classes: 424, 514, 435 and 800)[17] and over only the set of bio-pharmaceutical patents (USPTO patent classes: 435, 800). Hence, we calculate the total patent stocks, the total patent stocks in pharmaceuticals and the total patent stocks in biotechnology. The same classification is applied onto our patent yield and radical patents measures.

Our analytical framework distinguished three complementary hypothesis regarding the determinants of acquisitions in the pharmaceutical industry. Under the innovation gap hypothesis, acquirers are likely to own few patents, especially few high–quality patents while targets should have larger patent stocks with most of the influence associated to high quality patents. The absorptive capacity hypothesis slightly modifies this prediction for acquirers need to have to enough knowledge to successfully identify targets and incorporate their R&D assets. The absorptive capacity is reflected in its raw patent stock as well as the technological concentration of its portfolio, a greater absorptive capacity implying a lower concentration rate. Finally, the patent portfolio hypothesis states that firms are mainly seeking to acquire bundle of patents rather than innovative competencies. This implies that the number of patents owned by potential targets is a better predictor of target choices than the proportion of high quality patents in the patent stock.

4 Other Control Variables

Our regressions also incorporate two sub-industry indicators, one for firms belonging to the "*Pharmaceutical Industry*" sector as defined by the SIC codes 283x and one for firms belonging to the "*Medical Instruments*" as defined through the SIC codes 384x. All the remaining firms are grouped together and used as a reference. The

[17] See the USPTO classification. 424 and 514: "*drug, bio-affecting and body treating compositions*" ; 435: "*chemistry: molecular biology and microbiology*" and 800: "*multicellular living organisms and unmodified parts thereof and related processes*".

number of past acquisitions is incorporated in the regression for acquiring firms in order to account for possible experience effects in this type of operation. Finally, the number of years the firm is recorded in the *Compustat* file since 1965 is also used in order to incorporate effects related to the age of the firm.

V Results

1 Descriptive Statistics

Our dataset defines the pharmaceutical industry on a broad scale. Around a third of the sampled firms are classified in drug manufacturing (thereafter referenced as "*Pharmaceuticals*") by *Compustat*. Another third has its primary activity in medical instruments (thereafter referenced as "*Instruments*") and the last third is classified in other industries, mostly chemicals. Again, however, filtering the data through internet search confirmed that pharmaceuticals represented a substantial share of the manufacturing of the firms not classified into the drug industry by *Compustat*.[18]

The table (1) also reveals the heterogenous nature of the sample on our variables of interest since most of our variables display a high standard deviation. We can also note that on average the sampled firms are growing rapidly. For instance, the mean 3-year variation rate is +90% and the mean yearly growth rate of R&D investment is 25%. The average patent stock is of around 200 patents, but here again the standard deviation is high and some firms have much larger patent portfolios. Only a minority of these patents are granted in the four classes usually associated with pharmaceutical and bio-pharmaceutical preparations. The average patent stock in pharmaceuticals is 18 and only 3 in bio-pharmaceuticals treatments. The proportion of radical patents in the total patent stock is of 14%. It is much lower in the pharmaceutical and bio-pharmaceutical classes with respectively 5 and 2% of radical patents.

[18] Here follow some exemples of acquiring firms recoded as not belonging to the SIC category 283x: *APPLIED BIOSYSTEMS INC* (Pharmaceutical, Biotechnologies and standardized testing), *BAUSCH & LOMB INC* (Eye Health company), *GISH BIOMEDICAL INC* (Cardio-Technologies company), *SMITH LABORATORIES INC* (Generic Manufacturer).

Acquiring firms present a higher market value and a slightly higher growth rate in market value (relative to the total sample and thus to non–acquiring firms). Their Tobin's Q is slightly lower, but their R&D stock and the growth in R&D investment are higher. They own patent portfolios and the proportion of radical patents turns out to be slightly higher than average, but this could derive from their higher R&D investment. Also, acquiring firms less frequently belong to pure pharmaceutical sector, which is not surprising since by construction, the control group only includes firms from the pharmaceutical sector as defined by the SIC classification.

Finally, targeted firms present a lower market value than the average firm in our sample, but a much higher growth rate. Their Tobin's Q is much larger too. Their R&D stock is lower but their R&D investments grow at a higher rate. Their total patent stock is much lower than for the total sample, but they have a roughly comparable patent stock in pharmaceuticals and biotechnology. Regardless of the aggregation of technological classes, patent quality is higher for targets than for both the total sample and the sample of acquiring firms.

2 Results from the duration model

Table (2) presents the estimated coefficients obtained with the basic regression model. The acquiring firms tend to be larger firms (at least as measured by their market value) with a significant higher growth rate than non-acquiring ones (at least as measured by the growth of their market value in the years preceding the acquisition). Both variables are systematically significant at the 1% threshold, a result which is coherent with most of the previous evidence (Blonigen and Taylor, 2000; Danzon et al., 2004; Ornaghi, 2005; Dessyllas and Hughes, 2005a).

Acquiring firms also present a lower Tobin's Q, indicating that relative to their total assets, their market value is no longer very high. This effect is very robust and significant at the 1% threshold. Following Danzon et al. (2004) as well as Ornaghi (2005) who obtain similar results, this would confirm that purchasers of pharmaceu-

tical firms, or pharmaceutical acquiring firms, lack promising growth prospects, at least in the time horizon valued by financial investors. This result could be specific to the pharmaceutical industry, however. Indeed, the Q-theory of mergers predicts that firms with a higher Q should acquire firms with a lower Q. Related empirical evidence has been gathered by Jovanocic and Rousseau (2004) as well as Dessyllas and Hughes (2005a) on cross–industry samples. The lack of financial capacity by firms with a high Q in the bio-pharmaceutical sector could explain that such results are not found in this industry.

Results regarding the R&D capacity are rather supportive of our conclusions on the financial variables. First, acquiring firms present a lower R&D stock. The effect is particularly significant once the patent activity in pharmaceutical and bio-pharmaceutical is included in the regressions. Indeed, R&D stock and the patent stock are positively correlated, but exert opposing influences on the propensity to acquire other firms. Overall, this confirms the results obtained by Ornaghi (2005) for the large firms of the pharmaceutical industry as well as those by Blonigen and Taylor (2000) and Dessyllas and Hughes (2005a), who observe that the R&D intensity (defined as the R&D expenses over total assets) are negatively associated with the propensity to acquire. On the other hand, acquiring firms increase their R&D expenses in the years preceding the acquisition operation. The result is very robust, significant at the 1% threshold, and sits at odds with the notion that firms might reduce their R&D investment in order to finance their acquisition operations. Although this effect is minor, it suggests that acquisitions are complementary to an internal growth process materialized through an increase in R&D investment and that a sufficient absorptive capacity is a prerequisite to an acquisition in the pharmaceutical industry.

Overall, larger patent stocks in pharmaceuticals or in biotechnology encourage acquisitions. Indeed, although the total patent stock is not significant (model 1), the pharmaceutical patent stock exerts a positive and very significant influence (models

3 and 5), and so does the biotechnology patent stock (models 7 and 9). This result confirms the evidence gathered by Dessyllas and Hughes (2005a) on a cross-industry sample, where the stock of patents is also positively correlated to the decision to acquire. The influence of the patent yield is nil, indicating that firms that did not heavily resort to patents to protect their inventions or that are less productive in R&D are not more prone to acquire other companies. Dessyllas and Hughes (2005a) do not find significant coefficients for their measure of patent intensity (number of patents divided by total assets) either. Regardless of the technological classes, the proportion of radical patents is not a significant determinant of the propensity to acquire: acquiring firms are holders of large pharmaceutical and bio-pharmaceutical patent portfolios, but the average "quality" of their innovations is neither higher, nor lower than the average quality obtained for non–acquiring firms. Finally, the concentration rate of the patent portfolio across technological classes exerts a negative influence on the probability to acquire. The effect is very robust and significant at the 1% threshold. To summarize, acquirers face lower growth prospects (as indicated by their lower Tobin's Q) due to expirations of importants patents and the such, but their innovation gap is not as large as could have been presumed. On the contrary, they benefit from an absorptive capacity stemming from increases in R&D, large patent stocks, and a wide distribution of their patents across the technological classes.

As usual in the literature, the choice of targets turns out to be much more noisier than acquisition activity and the independent variables explain only a modest part of the probability of becoming a target.[19] Hence, few, if any, of the financial variables are significant. The growth in market value is higher for targets once their pharmaceutical patents are accounted for in the regressions, but this effect is only marginally significant. The R&D variables are not much decisive either. The R&D stock exerts a positive and significant influence (at the 10% threshold) when the pharmaceutical patents are excluded from the regressions, but this disappears once these variables are included in the regressions. Thus, a more ambitious R&D strategy increases some-

[19] See Dessyllas and Hughes (2005a), for a similar statement.

what marginally the probability to be targeted, but the underlying process is better captured through patent–based variables.

Neither the patent stock of potential targets, nor their patent yields exert any influence on the probability to be targeted. Hence, it is doubtful that over the 1978-2002 period, firms acquired other companies in order to enhance their patent portfolios. However, when looking at biotechnology patents, we do find that chosen targets present a larger patent portfolio than non-targeted firms. The effect is only significant at the 10% threshold, however. Hence, it might be that in biotechnology at least, acquisitions are at least partly driven by the need to acquire larger patent portfolios. However, as pointed above, average acquirers also present larger patent portfolios in biotechnology (as well as in pharmaceuticals). On the other hand, the proportion of radical patents (either overall or in pharmaceuticals) in the total patent stock displays a significant and positive coefficient. This positive influence is particularly strong and significant for the proportion of radical pharmaceutical patents (defined either relatively to the stock of pharmaceutical patents or to the total stock of patents). Hence, targeted firms run a higher risk (or enjoy a higher probability) of being targeted when their patent portfolio comprises a higher proportion of radical patents granted in the pharmaceutical technological classes. The concentration rate of the patent portfolio across technological classes does not influence target choice. Again, this may indicate that acquirers are not looking for patent portfolios as such, but for the radical innovations and competencies embedded in these patent portfolios.

Finally, unlike Ornaghi, our results also indicate that significant experience effects exist in the acquisition process: the past number of acquisitions positively and significantly influences the decision to acquire again. Acquiring and targeted firms are however younger than the sample average. Operations are more frequent in the "*Pharmaceutical*" and "*Instruments*" sub-sectors while he inclusion of the pharmaceutical patent stock makes the dummy "*Pharmaceutical*" insignificant (or almost) in the regressions concerning acquiring firms.

3 Synthesis

Acquiring firms in the (broadly defined) pharmaceutical industry present larger patent portfolios, a conclusion that had previously been found by Dessyllas and Hughes (2005a), which they interpreted as a proof acquiring firms tend to have a greater record of accumulated knowledge. A sufficient absorptive capacity seems thus needed to acquire other firms in the pharmaceutical industry, for instance to identify them or to exploit likely synergies necessary to make the acquisition a profitable operation. This conclusion is further confirmed when one considers that acquirers also hold patent portfolios that span various technological fields and make higher increases in R&D investments in the years preceding the acquisition operation. Both of these influences are very significant and robust. Also note that the average quality of the acquirers' patent portfolios is not lower than that of non-acquirers as the innovation gap theory would assume.

The "innovation gap" hypothesis therefore does not transpires through the patent positions of acquirers. However, as found by others in the literature, they acquirers present a lower Tobin's Q as well as from a lower R&D stock. Put besides past empirical evidence by Ornaghi (2005), Danzon et al. (2004) and Higgins and Rodriguez (2006), this confirms that acquirers suffer from declining growth prospects. On the other hand, our data show that the acquisition process that has been launched is not the deliberate consequence of an innovative labour division or from a make-or-buy strategy. On the contrary, acquiring firms have increasing R&D budgets.

Acquiring firms may therefore search for promising innovation prospects through a strong absorptive capacity. Supporting this statement, our regressions show that targets are chosen on the basis of the quality of their patent portfolio at least as measured by the proportion of radical patents either across technological fields but foremost in the pharmaceutical classes. Previous empirical evidence in this regard was very mild at best.

The patent portfolio hypothesis is only very weakly supported by our results. Targets do own larger patent portfolios in biotechnology probably because innovations in this industry are more and more complex (in the sense of Cohen et al., 2000) so that holding large patent portfolios has and will become an increasingly significant advantage. However, over the whole 1978-2002, this effect is only slightly significant, at the 10% threshold. The fact that firms with larger and less concentrated patent stock display a higher propensity to acquire also contradicts the patent portfolio hypothesis, which states that firms are using acquisitions to compensate for weak patent positions and to conduct their research more freely across various technological fields.

4 Robustness

To establish the robustness of our conclusions, several additional tests have been performed. First, all our patent variables were introduced sequentially into our regressions to establish whether any spurious correlation between them could blur our results. On the contrary, the estimated coefficients turned out to be very stable. Second, we introduced both the proportion of radical patents as well as the stock of radical patents in the regressions. Again, it turns out that targets display a higher proportion of radical patents, and that the stock of radical patents is not significant per se, except in the biotechnology technological classes (with similar significance as before, i.e., 10%). This confirms that acquirers are mostly looking for innovative competencies, not patents as such, except in the biotechnology field where this latter motive gains slightly more prominence. Third, we replaced the ratios of radical patent stocks to total patent stock with the shares of radical patents over the total number of patents granted in a given year. Even though the patent stock depreciates patent grants made farther in the past, this measure could underestimate the influence of recent patent grants. Taking shares of radical patents corrects this time bias by computing only the recent patent grants. Supplementary regressions thus included

two measures of radical patent shares, the share of radical patents the year before the operation is computed and the average of these shares over the 4 years preceding the acquisition operation (table 3). No significant change of our results was implied except that targets are apparently chosen on the basis of their share of radical patents, especially when this variable is averaged over four years. The patent stock in biotechnology is no longer a determinant of target choice. Hence, the already frail support for patent portfolio motivation is further weakened. Finally, estimations were also performed through panel Logit regressions[20]. Although the significance of some of the coefficients is slightly reduced, the overall pattern of results is left unchanged (see table 4).

We also introduce more financial variables (like the growth in sales, the income ratio – ratio of pre-tax profits over net capital – and the ratio of intangible assets over total assets – see table 5). Firms with higher sales growth or income ratio may be more prone to acquire firms with low sales growth or income ratio in order to exploit their competitiveness on external assets. Alternatively, the innovation gap framework would predict that companies with low sales growth or income ratio use acquisitions to enhance their their growth potential. Low sales growth and income ratio could also make a target more affordable. Finally, a high ratio of intangible assets to total assets should make the acquisition operation more difficult to finance. Such variables have found varying support in past empirical research. According to our results, acquiring firms are indeed suffering from lower growth in sales (measured from $t-3$ to $t-1$). This result, significant at the 1% threshold, further supports the "innovation gap" hypothesis since a decrease in revenue may be related to a patent expirations on a blockbuster drug. A similar conclusion was found in Danzon et al. (2004) and Ornaghi (2005).[21] It also appears the income ratio coefficient is negative

[20] Several empirical papers in this field use logit estimations to identify the determinants of acquisition behavior and target choices (Dessyllas and Hughes, 2005a,b; Ali-Yrrkö et al., 2005). Since Cox proportional hasard models are more general (they do make any assumption regarding the probability distribution of covariates), we have chosen to focus on a duration analysis.

[21] Additional regressions (not presented here) that included growth in sales for larger periods have also been implemented but the coefficients was not significant indicating the short term variation is a better predictor for the propensity to acquire than middle or long term variations in firms' sales.

and significant at the 5% level for targets and that targets present a higher growth in market value once we control for the income ratio. Thus, there is evidence that targets are facing a more difficult financial context than non-targets. Most importantly, none of our results regarding the impact of the patent portfolios are modified[22].

5 Differentiating by Dates and by Size

5.1 Differentiating by Dates of Operations

Our sample spans the years 1978 to 2002. Motives for acquisitions as well as target characteristics may have evolved over this long period of time. Indeed, the threat of generic competition has become much more pronounced over the years. Drug development costs have very substantially increased over that period, inducing a strong decline in productivity of research investments. Simultaneously, competition between pharmaceutical companies has increased, as testified, for instance, by the shortening of marketing exclusivity. Over this period, biotechnology has evolved from a mere research opportunity to a very significant source of innovation and of competition. The role of patents in the industry may also have changed over this period, not so much because of a strengthening of patent law (patents have always been relatively effective in protecting new pharmaceutical compositions) but because new pharmaceutical drugs have evolved from discrete to more complex innovations, protected by several patents instead of a single one. Finally, on a more general level, the sampled period covers two of the five merger waves identified by Jovanocic and Rousseau (2004) since 1890: the "refocusing wave" (from the beginning of the 80s to the beginning of the 90s) and the "global wave" (in the second half of the 90s). Some of the broader motives driving these merger waves (such as the need to refocus on core competencies or to acquire access to foreign markets) may also be present in the pharmaceutical industry.

[22] Still, one can observe that the variation in R&D investment is no longer significant for acquirers when the income ratio is introduced and that the Tobin's Q and the technological class concentration rate loose some of their significance.

Hence, we rerun our regressions onto three time periods of approximately equal number of observations, 1978-1985, 1986-1992 and 1993-2002 (table 6). Although the acquirer's market value as well as its experience in acquisition activity are very stable significant determinants of acquisition activity, the other patterns of influence turn out to be much more sensitive to the time period. Overall, we observe that our three hypothesis formulated in the survey section are mostly valid in the last time period (1993-2002).

Hence, a low Tobin's Q and or a low R&D stock are significant predictors of acquisition activity in the 1993-2002 period only, indicating that the "innovation gap" hypothesis has been valid mainly in the last decade or so. Prior to 1993, acquirers used to exhibit a greater variation in market value (than non-acquirers), but this is no longer the case in the 1993-2002 period. Again, this is supportive of the innovation gap hypothesis and so is the positive and significant coefficient for the proportion of radical pharmaceutical patents in the target regressions for the 1993-2002 period. It is therefore likely that in the preceding periods acquirers had different motives: for instance, it turns out that in the 1986-1992 period, targets exhibit a larger proportion of radical patents, but are not especially specialized in the pharmaceutical industry, as though acquirers were looking for diversified innovative competencies. Indeed, when the total proportion of radical patents is not included in the regressions for acquirers, the R&D stock exerts a strong positive influence on the probability to be acquired. Also coherent with this interpretation is the fact that targets exhibit high variation in market value and that acquirers have a high patent yield in biotechnology.

The "absorptive capacity" hypothesis also gains most of its empirical relevance in the last time period. Hence, acquirers in the 1993-2002 period exhibit a greater diversification of their patent grants. Although their total patent stock is lower, acquirers apparently need to be present in varied research segments in order to find acquisitions profitable. In conformity with the absorptive capacity, acquirers also own larger patent portfolios in both pharmaceuticals and biotechnology and choose

to increase their R&D investments in the years preceding an operation. With the exception of the pharmaceutical patent stock in the 1978-1985 period, none of these variables are significant in the previous periods.

Finally, the "patent portfolio" hypothesis, whose empirical relevance over the whole 1978-2002 period had been very limited, turns out to be more convincing in the last period. Indeed, targets exhibit larger patent portfolios in biotechnology as well as in pharmaceuticals, indicating that over the last decade, acquirers have paid greater attention to the patent position of potential targets.

5.2 Differentiating by Firms' Size

Motives for acquisitions may differ both with the acquirer's and target's sizes. For instance, small acquirers may be firms specialized in new drug discovery technologies. It is therefore uncertain whether they need to search for innovative potential in external firms in order to exploit in–house sales and marketing departments. Likewise, smaller companies are probably more focused on certain research segments so that they may not need a significant absorptive capacity to integrate the (necessarily) smaller targets that they acquire. On the other hand, the pressure to build up a wide patent portfolio may be stronger for these small companies because they lack the resources to build up such portfolios internally and because their low financial capacities and turnover make them ideal targets for patent trials.[23] Regarding targets, we may expect that among a group of small potential targets, those most likely to be acquired may display more specialized competencies and greater growth potential than targets among large firms. It is also so more likely that targets among small firms are chosen for a given set of valuable patents while large targets need to have supporting competencies in order to make the buy-out of a whole firm valuable.

Table (7) reruns our baseline regressions on two sub-samples. Our small–firm sample includes those companies whose averaged market value over the period 1978-

[23] See Lanjouw and Lerner (2001); Lerner (1995); Lanjouw and Schankerman (2004a) for related evidence.

2002 is inferior to the industrial median and the second sample comprises those with an exceeding averaged market value. Variables related to the innovation gap hypothesis (like the Tobin's Q and the R&D stock) perform similarly well in both samples of acquirers, indicating both small and large acquirers use acquisitions to enhance their growth prospects. For small acquirers, however, the "absorptive capacity" constraint seems much less binding: neither the growth in R&D investment, nor the patent portfolio concentration rate have significant explanatory power in the small–firm sample, although both of them are significant and with the expected signs in the large-firm sample. On the other hand, the patent portfolio hypothesis is not necessarily much more relevant in the case of small companies. Indeed, small acquirers own larger, not smaller, patent portfolios than small non–acquirers and they also display a high patent yield in pharmaceuticals. As expected, small potential targets seem to be discriminated upon the size of their patent portfolios, more than on the proportion of radical patents as is the case for large targets. They also display a higher market value growth, unlike large targets.

VI Conclusion

This articles uses a duration estimation model to identify the determinants of the individual propensity of firms to acquire or be targeted in the pharmaceutical and biopharmaceutical industry during the 1978-2002 period. Our theoretical framework comprises three distinct, not exclusive, hypotheses. The innovation gap model states that acquiring firms use these operations to get access to innovative competencies and products held by targets. The absorptive capacity hypotheses adds that only those firms with a sufficient absorptive capacity will resort to acquisition of innovative targets. Finally, the patent portfolio hypothesis considers that acquiring firms also intend to strengthen up their patent portfolios by acquiring firms with large patent portfolios.

To summarize, we find strong support for the first two of our hypothesis. Targeted

firms have a higher proportion of "radical patents" than non-targeted firms. Further, acquiring firms have lower Tobin's Q and lower R&D stock. Nonetheless, acquirers apparently have a substantial absorptive capacity: they have more patents than non-acquirers and an average proportion of radical patents. Their patents are also more diversified over technological classes than non acquirers and they choose to increase their R&D investment before acquiring another company.

Over the whole period, the patent acquisition motive does not seem to yield much explanatory power. Acquirers are not looking for large patent portfolios, whatever the indicator, but choose targets that have a high proportion of radical patents, thus indicating that innovative capacities matter more than legal appropriation tools. However, our estimations also indicate that over the last decade (1993-2002), the search for large patent portfolios has gained in significance in the biotechnology segment even though the targets' innovative performance remains an important selection criteria. It may also be more prominent for small targets.

VII Annexes and Econometric Tables

Figure 1: Radical patents identification criteria

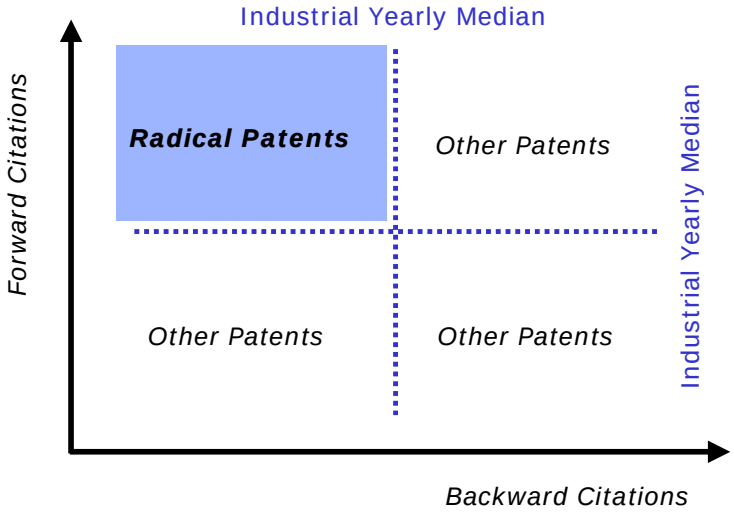

Table 1: Descriptives Statistics

Variable	Whole Sample		Acquirers Sample		Targeted Sample	
	Obs.	Mean	Obs.	Mean	Obs.	Mean
Market Value	5620	5890.49	608	18030.32	165	2989.87
Variation in Market Value (3 years)	5620	.90	608	1.01	165	1.41
Tobin's Q	5620	4.99	608	4.34	165	7.43
R&D stock	5620	436.38	608	1180.17	165	246.05
Variation in R&D investment (1 year)	5620	.24	608	.32	165	.35
Total patent stock	5620	199.24	608	335.92	165	56.00
Patent stock in pharmaceuticals	5620	18.89	608	50.56	165	16.28
Patent stock in biotechnology	5620	3.14	608	9.17	165	4.50
Patent intensity	5620	.31	608	.16	165	.10
Patent intensity in pharmaceuticals	5620	.01	608	.01	165	.02
Patent intensity in biotechnology	5620	.00	608	.00	165	.01
Proportion of radical patents	5620	.14	608	.17	165	.20
Proportion of pharmaceutical radical patents in pharmaceutical patent stock	5620	.05	608	.09	165	.09
Proportion of pharmaceutical radical patents in total patent stock	5620	.02	608	.03	165	.05
Proportion of biotechnology radical patents in biotechnology patent stock	5620	.02	608	.03	165	.04
Proportion of biotechnology radical patents in total patent stock	5620	.01	608	.01	165	.02
Technological Class Concentration	5620	.59	608	.41	165	.63
Number of years present in Compustat	5620	29.75	608	30.52	165	23.93
Number of past acquisitions	5620	.91	608	3.92	165	
"Pharmaceuticals"	5620	.32	608	.31	165	.40
"Instruments"	5620	.36	608	.46	165	.53

Table 2: Duration Model Estimations

	-1 Acquirers	-2 Targets	-3 Acquirers	-4 Targets	-5 Acquirers	-6 Targets	-7 Acquirers	-8 Targets	-9 Acquirers	-10 Targets
Tobin's Q	-0.020***	-0.003	-0.021***	-0.003	-0.021***	-0.003	-0.020***	-0.003	-0.020***	-0.004
	[0.007]	[0.003]	[0.007]	[0.003]	[0.007]	[0.003]	[0.007]	[0.003]	[0.007]	[0.003]
Log(Market Value)	0.246***	-0.090	0.256***	-0.108	0.259***	-0.104	0.252***	-0.107	0.252***	-0.105
	[0.049]	[0.072]	[0.048]	[0.075]	[0.049]	[0.074]	[0.048]	[0.074]	[0.048]	[0.075]
Variation in Market Value	0.025***	0.019	0.025***	0.022*	0.025***	0.022*	0.025***	0.022*	0.025***	0.022*
	[0.006]	[0.012]	[0.006]	[0.012]	[0.006]	[0.012]	[0.006]	[0.012]	[0.006]	[0.012]
Variation in R&D investment	0.067***	0.045	0.067***	0.041	0.067***	0.039	0.067***	0.041	0.067***	0.041
	[0.019]	[0.029]	[0.022]	[0.030]	[0.022]	[0.029]	[0.022]	[0.029]	[0.021]	[0.029]
Log(R&D stock)	-0.102*	0.244*	-0.173***	0.186	-0.177***	0.178	-0.162***	0.203*	-0.159***	0.202*
	[0.059]	[0.148]	[0.056]	[0.119]	[0.056]	[0.119]	[0.054]	[0.112]	[0.054]	[0.113]
Average Patent Yield	-0.082	-0.158								
	[0.196]	[0.382]								
Log(Total Patent Stock)	-0.092	-0.137								
	[0.057]	[0.158]								
Proportion of Radical Patents	0.313	1.301**								
in Total Stock	[0.295]	[0.535]								
Average Patent Yield			0.354	-1.315	0.405	-0.688				
in Pharmaceuticals			[0.409]	[2.406]	[0.401]	[1.934]				
Log(Patent Stock			0.118***	0.187*	0.114***	0.172				
in Pharmaceuticals)			[0.039]	[0.108]	[0.039]	[0.106]				
Proportion of Radical Pharmaceutical			0.604	2.898***						
Patents in Total Stock			[0.606]	[0.808]						
Proportion of Radical Pharmaceutical					0.378	1.595***				
Patents in Pharmaceutical Stock					[0.317]	[0.613]				
Average Patent Yield							1.106	0.751	0.865	0.874
in Biotechnology							[1.345]	[1.935]	[1.556]	[2.047]
Log(Patent Stock							0.095**	0.210*	0.095**	0.138*
in Biotechnology)							[0.040]	[0.126]	[0.044]	[0.139]
Proportion of Radical Biotechnology							-0.696	1.395		
Patents in Total Stock							[0.990]	[1.210]		
Proportion of Radical Biotechnology									-0.167	1.401**
Patents in Biotechnology Stock									[0.427]	[0.673]
Average Technological Class	-0.959***	-0.155	-0.466**	0.642	-0.460**	0.669	-0.618***	0.517	-0.614***	0.526
Concentration	[0.234]	[0.549]	[0.183]	[0.548]	[0.183]	[0.552]	[0.172]	[0.506]	[0.427]	[0.507]
Log(Firm's Age)	-0.287**	-1.269***	-0.356***	-1.310***	-0.374***	-1.397***	-0.378***	-1.335***	-0.365***	-1.334***
	[0.139]	[0.313]	[0.134]	[0.270]	[0.130]	[0.263]	[0.131]	[0.271]	[0.130]	[0.270]
Log(Number of Past Acquisitions)	0.579***		0.505***		0.501***		0.536***		0.539***	
	[0.049]		[0.053]		[0.052]		[0.050]		[0.050]	
"Pharmaceuticals"	0.209*	1.492***	0.079	1.244***	0.092	1.325***	0.229**	1.445***	0.222**	1.447***
	[0.113]	[0.412]	[0.122]	[0.424]	[0.118]	[0.422]	[0.109]	[0.420]	[0.109]	[0.419]
"Instruments"	0.654***	1.549***	0.788***	1.764***	0.789***	1.753***	0.714***	1.686***	0.709***	1.700***
	[0.107]	[0.422]	[0.104]	[0.420]	[0.105]	[0.420]	[0.105]	[0.416]	[0.104]	[0.416]
Observations	5620	5620	5620	5620	5620	5620	5620	5620	5620	5620

Robust standard errors in brackets.
***, ** and * respectively significant at the 1%, 5% and 10% thresholds.

Table 3: Duration Model Estimations – Shares of Radical Patents in Patenting

	-1 Acquirers	-2 Targets	-3 Acquirers	-4 Targets	-5 Acquirers	-6 Targets	-7 Acquirers	-8 Targets	-9 Acquirers	-10 Targets	-11 Acquirers	-12 Targets
Tobin's Q	-0.020***	-0.003	-0.020***	-0.003	-0.021***	-0.003	-0.021***	-0.004	-0.020***	-0.003	-0.020***	-0.003
	[0.007]	[0.003]	[0.007]	[0.003]	[0.007]	[0.003]	[0.007]	[0.003]	[0.007]	[0.003]	[0.007]	[0.003]
Log(Market Value)	0.245***	-0.097	0.243***	-0.087	0.259***	-0.107	0.260***	-0.100	0.253***	-0.107	0.253***	-0.108
	[0.048]	[0.072]	[0.049]	[0.073]	[0.048]	[0.074]	[0.048]	[0.074]	[0.048]	[0.074]	[0.048]	[0.075]
Variation in Market Value	0.025***	0.019*	0.025***	0.019*	0.025***	0.022*	0.025***	0.022*	0.025***	0.022*	0.025***	0.022*
	[0.006]	[0.010]	[0.006]	[0.012]	[0.006]	[0.012]	[0.006]	[0.012]	[0.006]	[0.012]	[0.006]	[0.012]
Variation in R&D investment	0.067***	0.044	0.067***	0.049*	0.066***	0.035	0.067***	0.037	0.067***	0.039	0.067***	0.040
	[0.019]	[0.028]	[0.019]	[0.029]	[0.022]	[0.029]	[0.022]	[0.029]	[0.022]	[0.029]	[0.022]	[0.029]
Log(R&D stock)	-0.100*	0.262*	-0.095	0.245*	-0.177***	0.180	-0.177***	0.179	-0.160***	0.197*	-0.160***	0.205*
	[0.058]	[0.139]	[0.058]	[0.145]	[0.056]	[0.119]	[0.056]	[0.119]	[0.054]	[0.113]	[0.054]	[0.113]
Average Patent Yield	-0.082	-0.124	-0.076	-0.176								
	[0.196]	[0.366]	[0.195]	[0.393]								
Log(Total Patent Stock)	-0.093*	-0.134	-0.095*	-0.146								
	[0.056]	[0.154]	[0.057]	[0.156]								
Share of Radical Patents	0.241	0.151										
	[0.161]	[0.310]										
Average Share			0.058	1.235**								
of Radical Patents			[0.301]	[0.501]								
Average Patent Yield					0.405	-0.733	0.395	-0.836				
in Pharmaceuticals					[0.403]	[1.872]	[0.403]	[2.064]				
Log(Patent Stock					0.117***	0.195*	0.110***	0.162				
in Pharmaceuticals)					[0.038]	[0.107]	[0.040]	[0.109]				
Share of Radical Patents					0.270	1.025***						
in Pharmaceuticals					[0.192]	[0.300]						
Average Share of Radical							0.474	1.765***				
Patents in Pharmaceuticals							[0.346]	[0.601]				
Average Patent Yield									0.767	1.124	0.743	1.018
in Biotechnology									[1.650]	[1.727]	[1.677]	[1.885]
Log(Patent Stock									0.084**	0.198	0.081*	0.139
in Biotechnology)									[0.041]	[0.130]	[0.047]	[0.144]
Share of Radical Patents									0.043	0.670*		
in Biotechnology									[0.241]	[0.384]		
Average Share of Radical											0.087	1.392**
Patents in Biotechnology											[0.477]	[0.680]
Average Technological Class	-0.958***	-0.255	-0.976***	-0.121	-0.463**	0.652	-0.457**	0.698	-0.609***	0.506	-0.607***	0.527
Concentration	[0.233]	[0.588]	[0.234]	[0.547]	[0.183]	[0.559]	[0.184]	[0.555]	[0.171]	[0.512]	[0.170]	[0.508]
Log(Firm's Age)	-0.291**	-1.362***	-0.301**	-1.290***	-0.378***	-1.433***	-0.369***	-1.411***	-0.361***	-1.362***	-0.361***	-1.359***
	[0.138]	[0.297]	[0.137]	[0.306]	[0.130]	[0.265]	[0.130]	[0.262]	[0.130]	[0.265]	[0.130]	[0.266]
Log(Number of Past Acquisitions)	0.578***		0.574***		0.502***		0.501***		0.540***		0.540***	
	[0.049]		[0.049]		[0.053]		[0.052]		[0.050]		[0.050]	
"Pharmaceuticals"	0.211*	1.561***	0.220*	1.492***	0.095	1.348***	0.090	1.334***	0.220**	1.463***	0.219**	1.452***
	[0.113]	[0.410]	[0.114]	[0.408]	[0.117]	[0.419]	[0.117]	[0.417]	[0.109]	[0.418]	[0.109]	[0.417]
"Instruments"	0.658***	1.645***	0.669***	1.572***	0.786***	1.753***	0.787***	1.751***	0.712***	1.693***	0.712***	1.684***
	[0.106]	[0.415]	[0.107]	[0.414]	[0.105]	[0.421]	[0.105]	[0.419]	[0.105]	[0.417]	[0.105]	[0.416]
Observations	5620	5620	5620	5620	5620	5620	5620	5620	5620	5620	5620	5620

Robust standard errors in brackets.
***, ** and * respectively significant at the 1%, 5% and 10% thresholds.

Table 4: Panel Logit Estimations

	-1 Acquirers	-2 Targets	-3 Acquirers	-4 Targets	-5 Acquirers	-6 Targets	-7 Acquirers	-8 Targets	-9 Acquirers	-10 Targets
Tobin's Q	-0.025**	-0.002	-0.028***	-0.002	-0.028***	-0.002	-0.026***	-0.002	-0.026***	-0.002
	[0.010]	[0.004]	[0.010]	[0.004]	[0.010]	[0.004]	[0.010]	[0.004]	[0.010]	[0.004]
Log(Market Value)	0.354***	-0.118	0.353***	-0.113	0.356***	-0.109	0.351***	-0.120	0.350***	-0.120
	[0.066]	[0.097]	[0.065]	[0.097]	[0.065]	[0.098]	[0.065]	[0.098]	[0.065]	[0.098]
Variation in Market Value	0.034***	0.018	0.034***	0.021	0.034***	0.021	0.034***	0.021	0.034***	0.021
	[0.011]	[0.017]	[0.011]	[0.017]	[0.011]	[0.017]	[0.011]	[0.017]	[0.011]	[0.017]
Variation in R&D investment	0.099**	0.094	0.095**	0.088	0.095**	0.089	0.097**	0.091	0.096**	0.092
	[0.044]	[0.065]	[0.043]	[0.074]	[0.042]	[0.074]	[0.043]	[0.072]	[0.043]	[0.072]
Log(R&D stock)	-0.120	0.290**	-0.178**	0.149	-0.182**	0.141	-0.151**	0.208*	-0.151**	0.206*
	[0.087]	[0.146]	[0.071]	[0.125]	[0.071]	[0.126]	[0.070]	[0.124]	[0.070]	[0.124]
Average Patent Yield	-0.057	-0.620								
	[0.302]	[0.549]								
Log(Total Patent Stock)	0.020	-0.347**								
	[0.076]	[0.137]								
Proportion of Radical Patents	0.153	1.430**								
in Total Stock	[0.465]	[0.677]								
Average Patent Yield			0.394	-0.441	0.466	-0.182				
in Pharmaceuticals			[0.947]	[1.924]	[0.933]	[1.824]				
Log(Patent Stock			0.202***	0.094	0.197***	0.083				
in Pharmaceuticals)			[0.054]	[0.122]	[0.055]	[0.126]				
Proportion of Radical Pharmaceutical			0.821	2.973**						
Patents in Total Stock			[0.941]	[1.306]						
Proportion of Radical Pharmaceutical					0.430	1.648*				
Patents in Pharmaceutical Stock					[0.538]	[0.949]				
Average Patent Yield							2.046	6.277	1.865	6.405
in Biotechnology							[3.174]	[4.168]	[3.170]	[4.156]
Log(Patent Stock							0.186***	-0.012	0.192***	0.000
in Biotechnology)							[0.071]	[0.166]	[0.072]	[0.167]
Proportion of Radical Biotechnology							-1.957	1.534		
Patents in Total Stock							[1.600]	[2.015]		
Proportion of Radical Biotechnology									-0.998	0.588
Patents in Biotechnology Stock									[0.781]	[1.277]
Average Technological Class	-0.409*	-0.828**	-0.255	-0.095	-0.253	-0.096	-0.403**	-0.193	-0.402**	-0.200
Concentration	[0.213]	[0.379]	[0.183]	[0.343]	[0.184]	[0.345]	[0.179]	[0.335]	[0.179]	[0.335]
Log(Firm's Age)	-0.395*	-1.395***	-0.330	-1.797***	-0.351*	-1.886***	-0.363*	-1.818***	-0.337*	-1.841***
	[0.218]	[0.364]	[0.201]	[0.332]	[0.197]	[0.329]	[0.201]	[0.337]	[0.199]	[0.335]
Log(Number of Past Acquisitions)	0.542***		0.457***		0.455***		0.496***		0.498***	
	[0.107]		[0.109]		[0.108]		[0.109]		[0.109]	
"Pharmaceuticals"	0.339**	1.346***	0.062	1.224***	0.082	1.305***	0.299*	1.409***	0.274*	1.430***
	[0.163]	[0.408]	[0.174]	[0.421]	[0.170]	[0.420]	[0.162]	[0.412]	[0.161]	[0.411]
"Instruments"	0.976***	1.654***	1.108***	1.835***	1.108***	1.853***	1.014***	1.817***	1.015***	1.819***
	[0.162]	[0.406]	[0.161]	[0.401]	[0.161]	[0.404]	[0.157]	[0.402]	[0.157]	[0.402]
Constant	-3.784***	0.068	-3.841***	0.376	-3.761***	0.605	-3.699***	0.355	-3.772***	0.431
	[0.783]	[1.268]	[0.761]	[1.206]	[0.749]	[1.204]	[0.762]	[1.235]	[0.757]	[1.228]
Time Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5620	5620	5620	5620	5620	5620	5620	5620	5620	5620

Robust standard errors in brackets.
***, ** and * respectively significant at the 1%, 5% and 10% thresholds.

Table 5: Duration Model Estimations – Financial Variables

	-1 Acquirers	**-2 Targets**	**-3 Acquirers**	**-4 Targets**	**-5 Acquirers**	**-6 Targets**
Variation in Sales	-0.000***	-0.035	-0.000***	-0.026	-0.000***	-0.026
(from t-3 to t-1)	[0.000]	[0.072]	[0.000]	[0.064]	[0.000]	[0.065]
Ratio of intangible Assets	-0.474	1.109	-0.432	0.756	-0.372	0.91
	[0.609]	[1.175]	[0.635]	[1.246]	[0.636]	[1.233]
Income ratio	0.016	-0.195***	0.026	-0.152**	0.035	-0.153**
	[0.125]	[0.069]	[0.124]	[0.067]	[0.127]	[0.073]
Tobin's Q	-0.017*	-0.016	-0.018*	-0.013	-0.016*	-0.013
	[0.009]	[0.012]	[0.010]	[0.011]	[0.009]	[0.011]
Log(Market Value)	0.253***	-0.002	0.266***	-0.045	0.254***	-0.043
	[0.060]	[0.100]	[0.062]	[0.102]	[0.060]	[0.103]
Variation in Market Value	0.024***	0.027***	0.024***	0.029***	0.024***	0.029***
	[0.007]	[0.007]	[0.007]	[0.006]	[0.007]	[0.006]
Variation in R&D investment	0.059	0.053	0.047	0.048	0.053	0.051
	[0.051]	[0.037]	[0.050]	[0.033]	[0.050]	[0.034]
Log(R&D stock)	-0.097	0.203	-0.171***	0.217*	-0.152**	0.217*
	[0.071]	[0.166]	[0.066]	[0.126]	[0.063]	[0.124]
Average Patent Yield	-0.095	-0.466				
	[0.208]	[0.576]				
Log(Total Patent Stock)	-0.080	-0.130				
	[0.072]	[0.174]				
Proportion of Radical Patents	0.192	1.587***				
in Total Stock	[0.347]	[0.568]				
Average Patent Yield			0.270	0.137		
in Pharmaceuticals			[0.381]	[1.412]		
Log(Patent Stock			0.138***	0.129		
in Pharmaceuticals)			[0.051]	[0.120]		
Proportion of Radical Pharmaceutical			0.408	1.766***		
Patents in Pharmaceutical Stock			[0.355]	[0.678]		
Average Patent Yield					1.313	1.708
in Biotechnology					[1.367]	[2.120]
Log(Patent Stock					0.142**	0.161
in Biotechnology)					[0.066]	[0.154]
Proportion of Radical Biotechnology					-0.373	1.235
Patents in Biotechnology Stock					[0.544]	[0.753]
Average Technological Class	-0.895***	-0.060	-0.358	0.876	-0.537**	0.777
Concentration	[0.273]	[0.615]	[0.229]	[0.593]	[0.212]	[0.554]
Log(Firm's Age)	-0.275	-1.253***	-0.324*	-1.385***	-0.294	-1.312***
	[0.198]	[0.351]	[0.186]	[0.302]	[0.190]	[0.305]
Log(Number of Past Acquisitions)	0.625***		0.538***		0.570***	
	[0.064]		[0.073]		[0.068]	
"Pharmaceuticals"	0.269**	1.338***	0.116	1.183**	0.267**	1.333**
	[0.135]	[0.506]	[0.137]	[0.528]	[0.125]	[0.520]
"Instruments"	0.677***	1.639***	0.797***	1.779***	0.718***	1.774***
	[0.130]	[0.524]	[0.131]	[0.523]	[0.126]	[0.522]
Observations	5819	5819	5819	5819	5819	5819

Robust standard errors in brackets.
***, ** and * respectively significant at the 1%, 5% and 10% thresholds.

Table 6: Duration Model Estimations – Different Time Periods

	1978-85						1986-92						1993-02					
	-1 Acquirers	-2 Targets	-3 Acquirers	-4 Targets	-5 Acquirers	-6 Targets	-7 Acquirers	-8 Targets	-9 Acquirers	-10 Targets	-11 Acquirers	-12 Targets	-13 Acquirers	-14 Targets	-15 Acquirers	-16 Targets	-17 Acquirers	-18 Targets
Tobin's Q	-0.053	-0.012	-0.088*	-0.013	-0.057	-0.016	-0.006	-0.003	-0.006	-0.003	-0.005	-0.003	-0.025***	0.001	-0.026***	-0.001	-0.025***	0.001
	[0.033]	[0.028]	[0.053]	[0.026]	[0.037]	[0.027]	[0.006]	[0.003]	[0.007]	[0.002]	[0.005]	[0.002]	[0.008]	[0.005]	[0.008]	[0.007]	[0.008]	[0.006]
Log(Market Value)	0.426***	0.014	0.490***	-0.039	0.426***	-0.013	0.223***	0.000	0.217***	-0.007	0.217***	-0.001	0.243***	-0.189*	0.280***	-0.159	0.274***	-0.203*
	[0.132]	[0.270]	[0.145]	[0.274]	[0.137]	[0.279]	[0.075]	[0.100]	[0.077]	[0.103]	[0.074]	[0.101]	[0.062]	[0.113]	[0.061]	[0.114]	[0.0560]	[0.117]
Variation in Market Value	0.082*	0.007	0.080*	0.014	0.085**	0.020	0.022***	0.027***	0.021***	0.026***	0.021***	0.026***	0.021*	-0.010	0.019	0.001	0.019	-0.004
	[0.043]	[0.058]	[0.042]	[0.050]	[0.042]	[0.047]	[0.007]	[0.007]	[0.007]	[0.006]	[0.007]	[0.006]	[0.013]	[0.021]	[0.013]	[0.025]	[0.013]	[0.025]
Variation in R&D investment	0.050	-0.065	-0.049	-0.137	-0.01	-0.132	0.076	0.043	0.073	0.035	0.081	0.026	0.062***	-0.127	0.075***	-0.100	0.072***	-0.098
	[0.147]	[0.272]	[0.172]	[0.272]	[0.146]	[0.289]	[0.052]	[0.038]	[0.051]	[0.033]	[0.051]	[0.032]	[0.020]	[0.221]	[0.023]	[0.189]	[0.024]	[0.192]
Log(R&D stock)	0.036	0.133	-0.063	0.104	-0.019	0.165	-0.048	0.301*	-0.093	0.357***	-0.088	0.345***	-0.094	0.267	-0.307***	-0.017	-0.277***	0.098
	[0.150]	[0.249]	[0.154]	[0.249]	[0.137]	[0.253]	[0.099]	[0.168]	[0.081]	[0.127]	[0.080]	[0.130]	[0.080]	[0.252]	[0.073]	[0.211]	[0.070]	[0.190]
Average Patent Yield	-0.054	-0.257					0.171	-0.494					0.090	0.290				
	[0.329]	[0.464]					[0.432]	[1.038]					[0.432]	[0.557]				
Log(Total Patent Stock)	-0.030	0.043					-0.011	-0.096					-0.239***	-0.239				
	[0.163]	[0.310]					[0.104]	[0.192]					[0.069]	[0.258]				
Proportion of Radical Patents	-0.905	1.769					0.546	1.487***					0.111	1.432*				
in Total Stock	[1.223]	[1.615]					[0.508]	[0.577]					[0.446]	[0.833]				
Average Patent Yield			0.808**	-15.667					1.144	1.057					-6.754*	-2.303		
in Pharmaceuticals			[0.401]	[10.417]					[0.712]	[1.717]					[3.506]	[5.386]		
Log(Patent Stock			0.387***	0.574*					0.152*	-0.132					0.130***	0.347**		
in Pharmaceuticals)			[0.111]	[0.339]					[0.079]	[0.152]					[0.048]	[0.148]		
Proportion of Radical Pharmaceutical			-1.782	3.727*					0.572	0.462					0.569	2.356***		
Patents in Pharmaceutical Stock			[1.661]	[2.254]					[0.545]	[1.004]					[0.386]	[0.812]		
Average Patent Yield					-2.635	-15.749					4.408***	-3.777					-10.248*	2.551
in Biotechnology					[29.929]	[68.610]					[1.553]	[4.174]					[6.047]	[2.062]
Log(Patent Stock					0.213	-0.025					0.165**	-0.285					0.137**	0.311*
in Biotechnology)					[0.142]	[0.395]					[0.080]	[0.201]					[0.060]	[0.170]
Proportion of Radical Biotechnology					-0.132	5.718					-0.504	1.100					0.153	1.426
Patents in Biotechnology Stock					[1.819]	[5.264]					[0.603]	[1.164]					[0.559]	[1.049]
Average Technological Class	-0.428	1.198	0.882	2.355	-0.038	1.507	-0.250	0.208	0.078	0.464	-0.121	0.391	-1.369***	-0.714	-0.717***	0.449	-0.715***	0.268
Concentration	[0.841]	[1.602]	[0.736]	[1.748]	[0.575]	[1.242]	[0.476]	[0.807]	[0.403]	[0.624]	[0.351]	[0.610]	[0.283]	[0.740]	[0.200]	[0.832]	[0.191]	[0.760]
Log(Firm's Age)	-1.075**	-1.353	-1.035*	-1.219	-1.014*	-0.964	-0.092	-1.696***	-0.005	-1.853***	0.087	-1.957***	-0.158	-0.856*	-0.482***	-1.106***	-0.442***	-0.928**
	[0.544]	[0.886]	[0.594]	[0.856]	[0.600]	[0.892]	[0.341]	[0.430]	[0.322]	[0.353]	[0.327]	[0.344]	[0.145]	[0.476]	[0.134]	[0.382]	[0.140]	[0.395]
Log(Number of Past Acquisitions)	0.708***		0.576***		0.671***		0.672***		0.568***		0.614***		0.535***		0.461***		0.497***	
	[0.197]		[0.191]		[0.210]		[0.098]		[0.113]		[0.099]		[0.059]		[0.063]		[0.062]	
"Pharmaceuticals"	0.421	0.709	0.073	0.309	0.317	0.5424	0.157	1.360**	-0.051	1.563**	0.115	1.597**	0.241	1.620***	0.262	1.242**	0.300*	1.461***
	[0.269]	[1.126]	[0.285]	[1.256]	[0.278]	[1.160]	[0.179]	[0.635]	[0.190]	[0.621]	[0.168]	[0.629]	[0.155]	[0.476]	[0.175]	[0.512]	[0.160]	[0.487]
"Instruments"	0.564**	1.983*	0.782**	2.147**	0.505*	2.146**	0.447**	1.745***	0.590***	1.825***	0.496***	1.840***	0.791***	1.050**	0.942***	1.457***	0.889***	1.461***
	[0.279]	[1.113]	[0.305]	[1.045]	[0.271]	[0.931]	[0.176]	[0.634]	[0.170]	[0.631]	[0.171]	[0.632]	[0.151]	[0.499]	[0.168]	[0.466]	[0.157]	[0.473]
Observations	1807	1807	1807	1807	1807	1807	1866	1866	1866	1866	1866	1866	1911	1911	1911	1911	1911	1911
Number of Firms	290	290	290	290	290	290	322	322	322	322	322	322	288	288	288	288	288	288
Number of Acquirers	80	80	80	80	80	80	219	219	219	219	219	219	361	361	361	361	361	361
Number of Targets	26	26	26	26	26	26	69	69	69	69	69	69	67	67	67	67	67	67

Robust standard errors in brackets.
***, ** and * respectively significant at the 1%, 5% and 10% thresholds.

Table 7: Duration Model Estimations – Differentiating Size

	Small Sized Firms (Market Value < Median)						Large Sized Firms (Market Value > Median)					
	-1	**-2**	**-3**	**-4**	**-5**	**-6**	**-7**	**-8**	**-9**	**-10**	**-11**	**-12**
	Acquirers	**Targets**	**Acquirers**	**Targets**	**Acquirers**	**Targets**	**Acquirers**	**Targets**	**Acquirers**	**Targets**	**Acquirers**	**Targets**
Tobin's Q	-0.045***	-0.005	-0.048***	-0.003	-0.042***	-0.003	-0.015**	-0.001	-0.016**	-0.000	-0.015**	-0.001
	[0.016]	[0.010]	[0.017]	[0.008]	[0.016]	[0.008]	[0.007]	[0.002]	[0.008]	[0.002]	[0.007]	[0.002]
Log(Market Value)	0.423***	0.136	0.411***	0.112	0.420***	0.116	0.216***	-0.099	0.232***	-0.116	0.222***	-0.100
	[0.086]	[0.113]	[0.086]	[0.112]	[0.085]	[0.112]	[0.070]	[0.139]	[0.068]	[0.143]	[0.068]	[0.142]
Variation in Market Value	0.028***	0.026***	0.030***	0.024***	0.028**	0.022***	0.022**	-0.002	0.020**	-0.005	0.020**	-0.006
	[0.011]	[0.009]	[0.011]	[0.008]	[0.011]	[0.008]	[0.009]	[0.014]	[0.009]	[0.014]	[0.009]	[0.016]
Variation in R&D investment	0.010	-0.001	0.006	0.015	0.013	0.023	0.078***	0.003	0.086***	0.009	0.086***	0.033
	[0.069]	[0.030]	[0.072]	[0.028]	[0.070]	[0.030]	[0.019]	[0.217]	[0.019]	[0.197]	[0.019]	[0.165]
Log(R&D stock)	-0.182*	0.176	-0.173**	0.197	-0.180**	0.223*	-0.074	0.257	-0.192***	0.240	-0.183***	0.258
	[0.094]	[0.168]	[0.082]	[0.136]	[0.078]	[0.132]	[0.091]	[0.222]	[0.074]	[0.215]	[0.069]	[0.195]
Average Patent Yield	-0.017	-0.098					-0.085	-3.882				
	[0.314]	[0.280]					[0.283]	[2.967]				
Log(Total Patent Stock)	0.054	0.151					-0.118	-0.145				
	[0.117]	[0.173]					[0.080]	[0.295]				
Proportion of Radical Patents	0.717	0.560					-0.309	1.776**				
in Total Stock	[0.492]	[0.711]					0.391]	[0.738]				
Average Patent Yield			0.766***	0.485					-0.717	-5.358		
in Pharmaceuticals			[0.148]	[0.537]					[1.539]	[5.141]		
Log(Patent Stock			0.261**	0.454***					0.126***	0.115		
in Pharmaceuticals)			[0.108]	[0.175]					[0.044]	[0.177]		
Proportion of Radical Pharmaceutical			-0.070	-0.745					0.330	2.718***		
Patents in Pharmaceutical Stock			[0.662]	[0.946]					[0.364]	[0.653]		
Average Patent Yield					0.725	1.934					-10.907	-17.656
in Biotechnology					[1.312]	[1.318]					[6.647]	[12.473]
Log(Patent Stock					0.576**	0.590***					0.129***	0.172
in Biotechnology)					[0.231]	[0.263]					[0.046]	[0.204]
Proportion of Radical Biotechnology					-1.343	-1.985					-0.152	2.596***
Patents in Biotechnology Stock					[1.190]	[1.802]					[0.482]	[0.703]
Average Technological Class	-0.260	0.095	-0.234	0.077	-0.360	-0.219	1.167***	-0.268	-0.586***	1.063	-0.776***	1.090*
Concentration	[0.363]	[0.597]	[0.270]	[0.570]	[0.275]	[0.516]	[0.302]	[0.826]	[0.222]	[0.745]	[0.201]	[0.685]
Log(Firm's Age)	-0.087	-1.577***	-0.032	-1.432***	0.114	-1.293***	0.594***	-1.461*	-0.694***	-1.640***	-0.711***	-1.624***
	[0.311]	[0.311]	[0.272]	[0.292]	[0.268]	[0.310]	[0.161]	[0.764]	[0.141]	[0.568]	[0.136]	[0.597]
Log(Number of Past Acquisitions)	0.336***		0.297***		0.291**		0.662***		0.592***		0.633***	
	[0.112]		[0.115]		[0.112]		[0.055]		[0.054]		[0.052]	
"Pharmaceuticals"	-0.029	0.985	-0.346	0.597	-0.145	0.824	0.284**	1.836***	0.170	1.829***	0.302**	1.869***
	[0.245]	[0.641]	[0.271]	[0.653]	[0.255]	[0.665]	[0.132]	[0.469]	[0.127]	[0.510]	[0.119]	[0.465]
"Instruments"	0.730***	1.734***	0.782***	1.804***	0.793***	1.764***	0.674***	1.063*	0.814***	1.446**	0.716***	1.381**
	[0.181]	[0.629]	[0.176]	[0.637]	[0.174]	[0.621]	[0.130]	[0.638]	[0.127]	[0.572]	[0.124]	[0.597]
Observations	3448	3448	3448	3448	3448	3448	3485	3485	3485	3485	3485	3485
Number of Firms	249	249	249	249	249	249	159	159	159	159	159	159
Number of Acquirers	197	100	197	100	197	100	463	62	463	62	463	62
Number of Targets	3448	3448	3448	3448	3448	3448	3485	3485	3485	3485	3485	3485

Robust standard errors in brackets.
***, ** and * respectively significant at the 1%, 5% and 10% thresholds.

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